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Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE**UTILITY
PATENT APPLICATION
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Attorney Docket No. 042390.P8746

First Inventor or Application Identifier Tinku Acharya

Title METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

Express Mail Label No. EL034434615US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents

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1. ☒ Fee Transmittal Form
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- Descriptive title of the Invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
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☐ Continuation ☐ Divisional ☒ Continuation-in-part (CIP)

of prior application No: 09/410,870

Prior application Information: Examiner

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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

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METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

RELATED APPLICATION

5 This patent application is a continuation-in-part of US Patent Application Serial No. 09/410,800, titled "Method of Interpolation Color Pixel Signals from a Subsampled Color Image," by Acharya et al., filed on October 1, 1999, assigned to the assignee of the present invention and herein incorporated by reference.

BACKGROUND

10 This disclosure is related to interpolating color pixel signal values for an image and, in particular, interpolating color pixel signal values using hue.

15 As is well-known, in a variety of circumstances, it is desirable to perform color interpolation. For example, for a camera or other imager that has the capability of creating a color image, typically it is too expensive to have the capability to capture three independent color pixel signal values for each pixel location of an image at least on part because this would employ additional sensors. Therefore, more typically, a subsampled color image is captured and then the missing color pixel signal values are computed using techniques of color interpolation. Most of the existing simple color interpolation techniques typically do not produce high-quality color images. Therefore, a need continues to exist for color interpolation

20

techniques capable of producing quality color images from a subsampled color image.

BRIEF DESCRIPTION OF THE DRAWINGS

5

The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

10

FIG. 1 is a schematic diagram illustrating a subsampled color image, such as a Bayer pattern color image;

15

FIG. 2 is a schematic diagram illustrating a portion of a subsampled color image in which the color pixel signal values are to be employed by an embodiment of a method in accordance with the present invention;

20

FIG. 3 is a schematic diagram illustrating a portion of another subsampled color image in which the color pixel signal values are to be employed by an embodiment of a method in accordance with the present invention;

FIG. 4 is a schematic diagram illustrating yet another portion of a subsampled color image in which the color pixel signal values are to be employed by an embodiment of a

method in accordance with the present invention.

DETAILED DESCRIPTION

5 In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components and circuits have not been described in detail so as not to obscure the present invention.

10 As previously indicated, in a variety of circumstances it may be desirable to have a capability to interpolate color pixel signals from a subsampled color image in order to recover the missing color components in a particular pixel location. FIG. 1 is a schematic diagram illustrating a Bayer pattern color image, which is one example of a subsampled color image,
15 although the invention is not limited in scope in this respect. For example, many other well-known subsampled color images may be employed and will provide satisfactory results. As previously indicated, unfortunately, many color interpolation techniques typically do not produce high-quality color images at least in part because the techniques employed typically do not take into account, or at least reasonably correctly take into account, how the human
20 eye perceives color. For example, a typical color interpolation technique may include averaging the pixels adjacent to a particular pixel location in which it is desired to interpolate the color signal value for those colors not included in that pixel location of a subsampled color image. However, typically, simply employing a pure average does not produce high quality results at least in part because it may blur the edge information and produce a color bleeding

problem, for example.

In this particular embodiment of a method of using hue to interpolate color pixel signals in accordance with the present invention, color interpolation is accomplished by comparing, for a particular pixel location in a subsampled color image, relative differences in hue for two mutually orthogonal directions across the particular pixel location. Hue, in this context, for red and blue, refers to the relative signal value of a blue or red signal value to a green signal value at a given pixel location. It is assumed that if a significant change in hue occurs in a particular direction, the color pixel signal values in that direction are not as representative of the color pixel signal values at the particular pixel location as are the color pixel signal values from the mutually orthogonal direction. For example, it may be that in the image, an edge is being encountered. Therefore, in computing the color signal value for that particular pixel location, the change in hue for a direction that indicates less change in hue is weighed more heavily, in this particular embodiment. It is believed that this is more representative of how the human eye perceives color because the human vision system is more responsive to the relative change of color in neighboring pixels than to the color information in the pixel itself. In addition, as explained in more detail hereinafter, in computing pixel signal values for particular colors, the change in hue from both directions are weighed, instead of only using the change in hue from one direction to the exclusion of the other direction.

FIG. 2 is schematic diagram illustrating a portion of a five pixel-by-five pixel grid of the Bayer pattern of FIG. 1. As illustrated, the center pixel location comprises a red pixel signal value. Therefore, for this particular pixel location, it is desired to interpolate the missing color signal values, blue and green, for that pixel location from the surrounding pixel signal values.

For example, a green pixel signal value may be estimated as follows. First, the relative change in hue for the horizontal direction and the vertical directions with respect to this particular pixel location, designated below as RCH_hor and RCH_ver, respectively, may be computed and compared. This is accomplished using the following equations.

$$\text{RCH_hor} = | \frac{1}{2} \times [-R_{m,n-2} + 2 G_{m,n-1} - 2 G_{m,n+1} + R_{m,n+2}] |$$

[1]

$$\text{RCH_ver} = | \frac{1}{2} \times [-R_{m-2,n} + 2 G_{m-1,n} - 2 G_{m+1,n} + R_{m+2,n}] |$$

It is noted that for convenience, for the equations throughout the text of this specification, such as equations [1] above, it is assumed that the pixel signal values employed, such as $R_{i,j}$ or $G_{i,j}$, for example, are the logarithm of the pixel signal values having the corresponding designation from the subsampled image.

If the relative change in hue in the vertical direction is greater than the relative change in hue in the horizontal direction, then the values in the horizontal direction, that is, in this embodiment, the green and red pixel signal values that are the immediately adjacent pixel signal values in the horizontal direction, are weighed more heavily. In this embodiment, the weight assigned to these, 0.5 here, has been chosen based at least in part on fuzzy assignment concepts and experimentation, although the invention is not limited in scope in this respect. It is noted that other weights may be employed and provide satisfactory results. At the same time, the weights assigned to vertical signal values have been chosen as 0.1, although the invention is not limited in scope in this respect. On the basis of the above discussion, the missing green pixel signal values in this particular pixel location is estimated, in this embodiment, as

$$G_{m,n} = [0.5 * (I_{hor}) + 0.1 * (I_{ver})] / (0.5 + 0.1); \text{ or}$$

$$G_{m,n} = 2[0.41667 * (I_{hor}) + 0.08333 * (I_{ver})];$$

where

[2]

$$I_{hor} = (G_{m-1,n} + G_{m+1,n})/2 + 0.5 \times (-R_{m-2,n} + 2 R_{m,n} - R_{m+2,n})/4$$

$$I_{ver} = (R_{m,n-1} + R_{m,n+1})/2 + 0.5 \times (-R_{m,n-2} + 2 R_{m,n} - R_{m,n+2})/4$$

If the relative change in hue in the horizontal direction is greater than the relative change in hue in the vertical direction, then a reverse approach is employed. More particularly, the pixel signal values in the alternate directions, in this particular embodiment, are weighed more heavily. In particular, the green pixel signal value in this particular pixel signal location for such a situation is estimated as follows.

$$G_{m,n} = 2[0.08333 * (I_{hor}) + 0.41667 * (I_{ver})];$$

It is noted that the form of this equation is similar to the form above, except that the vertical and horizontal pixel signal values that were computed are interchanged. Finally, if the two relative changes are equal, or substantially equal, then a simple average of I_{ver} and I_{hor} are employed in this embodiment.

$$G_{m,n} = 0.5 * (I_{hor} + I_{ver});$$

Therefore, in order to compute the signal value for the green color plane, where the particular pixel location has a pixel signal value in the red color plane, the relative change in hue in mutually orthogonal directions is compared. It is noted that where the particular pixel location has a blue pixel signal value in the Bayer pattern shown in FIG. 1, the structure of a five pixel-by-five pixel portion of the sub-sampled color image is similar in arrangement to that illustrated in FIG. 2, except the center pixel contains blue signal information instead of red signal information. Therefore, for a pixel location containing a blue signal value, in this embodiment, the missing green pixel signal value for that pixel location may be estimated by using a technique essentially the same as one previously described, replacing the red pixel signal value used in the equations above for a particular location with the blue pixel signal value for the particular location now being considered.

FIG. 3 is schematic diagram of another portion of the Bayer pattern of FIG. 1. This three pixel-by-three pixel portion is similar to a three-by-three portion of FIG. 2, except that pixel signal values in the respective corners of the three-by-three array have also been provided. For this portion, it is desirable to interpolate a blue pixel signal value for the location in which a red pixel signal value is provided. However, as illustrated in FIG. 3, blue pixel signal values immediately adjacent to the red pixel signal value are provided in the corners. Therefore, in contrast with the approach just described, the two mutually orthogonal directions to be compared comprise the main diagonal and the secondary diagonal of the array of pixels. Therefore, the relative change in hue across these two diagonals shall be compared. Hue, in this context, for red and blue, refers to the relative signal value of a blue or red signal value to a green signal value at a given pixel location. As previously indicated, the reason this approach is employed is because it is believed that hue information more

accurately reflects how the human eye perceives changes in color. Furthermore, a comparison for red and blue pixel signal values is made with green pixel signal values because, in Red-Green-Blue (RGB) color space format, the green plane includes a relatively larger amount of luminosity signal information compared to the red and blue planes. Hue for red or blue signal values, therefore, is estimated by comparison with the green value. Therefore, hue for the four blue pixel signal values is computed by comparing the blue pixel signal value in that location with the green pixel signal value in that location. It should be noted that the missing green pixel value has already been or may be recovered via the previous technique. Therefore, the following equations apply.

$$\begin{aligned} \text{hue_nw} &= B_{m-1,n-1} - G_{m-1,n-1}; \\ \text{hue_sw} &= B_{m+1,n-1} - G_{m+1,n-1}; \end{aligned} \quad [3]$$

$$\begin{aligned} \text{hue_ne} &= B_{m-1,n+1} - G_{m-1,n+1}; \\ \text{hue_se} &= B_{m+1,n+1} - G_{m+1,n+1}; \end{aligned}$$

Then, the related change in hue along the main diagonal and the secondary diagonal may be computed as follows.

$$\text{hue_md} = | \text{hue_nw} - \text{hue_se} |; \quad [4]$$

$$\text{hue_sd} = | \text{hue_ne} - \text{hue_sw} |;$$

As discussed above, if the hue in any particular direction changes more significantly, then the hue in the mutually orthogonal direction is employed to estimate the blue pixel signal value in a particular pixel location. More accurately, that direction in which there is less relative change in hue is weighed more heavily than in the direction in which the relative change in hue is greater. Employing the relative change in hue in this fashion, the blue pixel signal value may be estimated as follows, assuming the relative relative change in hue along the main diagonal is less.

$$B_{m,n} = (G_{m,n}) + 0.41667 * ((B_{m-1,n+1} - G_{m-1,n+1}) + (B_{m+1,n+1} - G_{m+1,n+1})) + 0.08333 * ((B_{m-1,n+1} - G_{m-1,n+1}) + (B_{m+1,n+1} - G_{m+1,n+1})); \quad [5]$$

Likewise, a similar equation is employed for the opposing diagonal, except that the signal values along the diagonals are interchanged, providing the following equation.

$$(B_{m,n}) = (G_{m,n}) + 0.08333 * ((B_{m-1,n+1} - G_{m-1,n+1}) + (B_{m+1,n+1} - G_{m+1,n+1})) + 0.41667 * ((B_{m-1,n+1} - G_{m-1,n+1}) + (B_{m+1,n+1} - G_{m+1,n+1})) \quad [6]$$

It is noted that interpolation of a red pixel signal value for a particular pixel location having a blue pixel signal value may be obtained using a similar approach except that in the above equation the blue pixel signal values are interchanged with red pixel signal values. This is because, as illustrated in FIG. 1, where the particular pixel location has a blue pixel

signal value, the pixel signal values in the four corners are red pixel signal values, providing substantially the same structure or array layout as illustrated in FIG. 3. Finally, a blue pixel signal value may be interpolated where a green pixel signal value is provided in the particular pixel location of the subsampled image, as illustrated in FIG. 4, for example. The approach is similar to that described in connection to the approach described with FIG. 3, except that, instead of employing the pixel signal values along the diagonals, the horizontal and vertical pixel signal values are employed using either horizontal or vertical pixel signal value directly available from the subsampled color image. The other pixel value in the orthogonal direction which is used for interpolation is obtained by employing the previous calculation. For example, the blue pixel signal values in the horizontal locations immediately adjacent the green pixel signal values in FIG. 4 are interpolated using the approach just described above in connection with FIG. 3. Therefore, the following equations are employed.

$$\text{hue_n} = B_{m-1,n} - G_{m-1,n};$$

$$\text{hue_e} = B_{m,n+1} - G_{m,n+1};$$

[7]

$$\text{hue_w} = B_{m,n-1} - G_{m,n-1};$$

$$\text{hue_s} = B_{m+1,n} - G_{m+1,n};$$

$$\text{hhor} = \text{hue_e} - \text{hue_w};$$

$$\text{hver} = \text{hue_n} - \text{hue_s};$$

where $B_{m,n+1}$ and $B_{m,n-1}$ are obtained from the previous interpolation calculation.

if (| hhor | < | hver |) then

$$(B_{m,n}) = (G_{m,n}) + 0.41667 * ((B_{m,n-1} - G_{m,n-1}) + (B_{m,n+1} - G_{m,n+1})) +$$

$$0.08333 * ((B_{m-1,n} - G_{m-1,n}) + (B_{m+1,n} - G_{m+1,n})).$$

else

$$(B_{m,n}) = (G_{m,n}) + 0.08333 * ((B_{m,n-1} - G_{m,n-1}) + (B_{m,n+1} - G_{m,n+1})) + \\ 0.41667 * ((B_{m-1,n} - G_{m-1,n}) + (B_{m+1,n} - G_{m+1,n}))$$

5 **endif**

A similar approach may be employed to interpolate the red pixel signal value where the particular pixel location of the subsampled image includes a green pixel signal value, except that in the equations provided above, the blue pixel signal values are replaced by red pixel signal values, as follows

$$\text{hue_n} = R_{m-1,n} - G_{m-1,n};$$

$$\text{hue_e} = R_{m,n+1} - G_{m,n+1};$$

$$\text{hue_w} = R_{m,n-1} - G_{m,n-1};$$

[8]

$$\text{hue_s} = R_{m+1,n} - G_{m+1,n};$$

$$\text{hhor} = \text{hue_e} - \text{hue_w};$$

$$\text{hver} = \text{hue_n} - \text{hue_s},$$

20 where $R_{m-1,n}$ and $R_{m+1,n}$ (or $R_{m,n-1}$ and $R_{m,n+1}$ depending on whether the particular pixel is located in the red-green row or blue-green row) are obtained from the previous interpolation calculation.

if (| hhor | < | hver |) **then**

$$(R_{m,n}) = (G_{m,n}) + 0.41667 * ((R_{m,n-1} - G_{m,n-1}) + (R_{m,n+1} - G_{m,n+1})) + \\ 0.08333 * ((R_{m-1,n} - G_{m-1,n}) + (R_{m+1,n} - G_{m+1,n})).$$

else

5
$$(R_{m,n}) = (G_{m,n}) + 0.08333 * ((R_{m,n-1} - G_{m,n-1}) + (R_{m,n+1} - G_{m,n+1})) + \\ 0.41667 * ((R_{m-1,n} - G_{m-1,n}) + (R_{m+1,n} - G_{m+1,n}))$$

endif

It will, of course, be appreciated that the invention is not restricted in scope to a particular embodiment or implementation. For example, the foregoing approach, as one example of an approach in accordance with the invention, may be implemented in hardware, in software, in firmware, and/or any combination thereof. Again, intended merely as examples that do not limit the scope of the invention, an embodiment may comprise an imager including hardware, such as integrated circuit chips, that implement the foregoing. Alternatively, the imager may be coupled to a computing platform that includes software capable of implementing the foregoing. Likewise, a digital camera coupled to a desktop personal computer, for example, may implement an embodiment. Furthermore, these implementations in hardware and software may, of course, deviate from the foregoing and still be within the scope of the present invention.

For embodiments that are at least partially implemented in software, such as, for example, the previously described embodiment, such software may reside on a storage medium, such as, for example, random access memory, a CD ROM, a floppy disk, or a hard drive, such that instructions are stored, which, when executed, such as by a computing

platform, such as a PC or other computing device, so that the system is capable of executing the instructions to result in the interpolation of color pixel signal values from a subsampled image. Likewise, such software may reside in firmware also, such as in flash memory or EEPROM, for example.

5

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

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Claims:

- 1 1. A method of using hue to interpolate color pixel signal values comprising:
2 for a particular pixel location in a subsampled image, comparing relative changes in
3 hue for two mutually orthogonal directions across said particular pixel location; and
4 computing a color signal value for that particular pixel location for a color plane other
5 than the color plane of the pixel signal value in the subsampled color image at that location,
6 the computation including relatively weighing the relative changes in hue, the relative weights
7 depending, at least in part, on the difference in hue value in one particular direction relative to
8 the other.
- 1 2. The method of claim 1, wherein computing a color signal includes relatively weighing
2 the differences in hue by relatively weighing more heavily the difference in hue associated
3 with the direction having a difference in hue less relatively for the particular pixel location.
- 1 3. The method of claim 2, wherein the subsampled image comprises an image in RGB
2 color space format.
- 1 4. The method of claim 3, wherein the subsampled color image comprises a Bayer
2 pattern.
- 1 5. The method of claim 4, wherein the color plane of the pixel signal value at said
2 particular pixel location comprises the R color plane;
3 the two mutually orthogonal directions comprising the horizontal and vertical directions;

the particular color plane for the color signal value being computed comprising the G plane.

6. The method of claim 4, wherein the color plane of the pixel signal value at said particular pixel location comprises the B color plane;

the two mutually orthogonal directions comprising the horizontal and vertical direction; and

the particular color plane for the color signal value being computed comprising the G plane.

7. The method of claim 4, wherein the color plane of the pixel signal value at said particular pixel location comprises the R color plane;

the two mutually orthogonal direction comprising the main diagonal and the secondary diagonal directions;

the particular color plane for the color signal value being computed comprising the B plane.

8. The method of claim 7, wherein the interpolation of a blue pixel signal value at a green pixel location is based at least in part on computed B pixel signal value levels for red pixel locations adjacent said green pixel location and also on existing blue pixel locations adjacent said green pixel location in a mutually orthogonal direction to said adjacent red pixel locations in the subsampled color image.

9. The method of claim 4, wherein the color plane of the pixel signal value at said

particular pixel location comprises the B color plane;

the two mutually orthogonal directions comprising the main diagonal and the secondary diagonal directions;

the particular color plane for the color signal value being computed comprising the R plane.

10. The method of claim 9, wherein the interpolation of a red pixel signal value at a green pixel location is based at least in part on computed R pixel signal value levels for blue pixel locations adjacent said green pixel location and also on existing red pixel locations adjacent said green pixel location in a mutually orthogonal direction to said adjacent blue pixel locations in the subsampled color image.

11. The method of claim 4, wherein the color plane of the pixel signal value at said particular pixel location comprises the G color plane;

the two mutually orthogonal direction comprising the horizontal and the vertical directions;

the particular color plane for the color signal value being computed comprising the B plane.

12. The method of claim 4, wherein the color plane of the pixel signal value at said particular pixel location comprises the G color plane;

the two mutually orthogonal direction comprising the horizontal and the vertical directions;

the particular color plane for the color signal value being computed comprising the R

6 plane.

1 13. An article comprising:

2 a storage medium, having stored thereon instructions, which, when executed by a
3 system capable of executing the instructions, result in interpolating color pixel signal values
4 from a subsampled image by:

5 for a particular pixel location in the subsampled image, comparing changes in hue for
6 two mutually orthogonal directions across said particular pixel location; and

7 computing a color signal value for that particular pixel location for a color plane other
8 than the color plane of the pixel signal value in the subsampled color image at that location by
9 relatively weighing the differences in hue, the relative weights depending, at least in part, on
10 the difference in hue in a particular direction relative to the other direction.

1 14. The article of claim 13, wherein the instructions, when executed, further result in
2 interpolating color pixel signal values from a subsampled image in RGB color space format.

1 15. The article of claim 13, wherein the instructions, when executed, further result in
2 interpolating color pixel signal values from a Bayer pattern image.

1 16. An integrated circuit comprising;

2 electronic circuitry adapted to process pixel signal values;

3 wherein said electronic circuitry is further adapted to interpolate color pixel signal
4 values from a subsampled image by:

5 for a particular pixel location in the subsampled image, comparing changes in hue for

two mutually orthogonal directions across said particular pixel location; and

computing a color signal value for that particular pixel location for a color plane other than the color plane of the pixel signal value in the subsampled color image at that location by relatively weighing the differences in hue, the relative weights depending, at least in part, on the difference hue in a particular direction relative to the other direction.

17. The integrated circuit of claim 16, wherein said electronic circuitry is further adapted to interpolate color pixel signal values from a subsampled image in RGB color space format.

18. The integrated circuit of claim 16, wherein said electronic circuitry is further adapted to interpolate color pixel signal values from a Bayer pattern image.

19. A system comprising;
a computing platform adapted to process pixel signal values;
wherein said computing platform is further adapted to interpolate color pixel signal values from a subsampled image by:

for a particular pixel location in the subsampled image, comparing differences in hue for two mutually orthogonal directions across said particular pixel location; and
computing a color signal value for that particular pixel location for a color plane other than the color plane of the pixel signal value in the subsampled color image at that location by relatively weighing the difference in hue, the relative weights depending, at least in part, on the difference in hue in a particular direction relative to the other direction.

20. The system of claim 19, wherein said computing platform is further adapted to

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Briefly, in accordance with one embodiment of the invention, a method of using hue to interpolate color pixel signals includes the following. For a particular pixel location in a subsampled color image, differences in hue are compared for two mutually orthogonal directions across the particular pixel location. A color signal value for that particular pixel location for a color plane other than the color plane of the pixel signal value in the subsampled color image of that location is computed. The computation includes relatively weighing the differences in hue values, the relative weights depending, at least in part, on the difference in hue value in one direction relative to the other.

[illegible]

Figure 1: Bayer Pattern

		$R_{m-2,n}$		
		$G_{m-1,n}$		
$R_{m,n-2}$	$G_{m,n-1}$	$R_{m,n}$	$G_{m,n+1}$	$R_{m,n+2}$
		$G_{m+1,n}$		
		$R_{m+2,n}$		

Figure 2

$B_{m-1,n-1}$	$G_{m-1,n}$	$B_{m,n+1}$
$G_{m,n-1}$	$R_{m,n}$	$G_{m,n+1}$
$B_{m+1,n-1}$	$G_{m+1,n}$	$R_{m+,n+1}$

Figure 3

	$B_{m-1,n}$	
$R_{m,n-1}$	$G_{m,n}$	$R_{m,n+1}$
	$B_{m+1,n}$	

Figure 4

(FOR INTEL CORPORATION PATENT APPLICATIONS)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD OF USING HUE TO INTERPOLATE COLOR PIXEL SIGNALS

the specification of which



is attached hereto.

**DECLARATION AND POWER OF /
(FOR INTEL CORPORATION)**

was filed on _____ as _____

United States Application Number _____

or PCT International Application Number _____

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

APPLICATION NUMBER	COUNTRY (OR INDICATE IF PCT)	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 37 USC 119
			<input type="checkbox"/> No <input type="checkbox"/> Yes
			<input type="checkbox"/> No <input type="checkbox"/> Yes
			<input type="checkbox"/> No <input type="checkbox"/> Yes

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION NUMBER	FILING DATE	STATUS (ISSUED, PENDING, ABANDONED)
09/440,800	10/11/99	Pending

I hereby appoint the persons listed on Appendix A hereto (which is incorporated by reference and a part of this document) as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to:

Howard A. Skaist, Reg. No. 36,008, BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN, LLP

(Name of Attorney or Agent)

12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025 and direct telephone calls to:

Howard A. Skaist, (503) 684-6200.

(Name of Attorney or Agent)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole/First Inventor (given name, family name)

Tinku Acharya

Inventor's Signature _____

Date _____

Residence _____
(City, State)

Citizenship _____
(Country)

P. O. Address _____

002739 49376550

Full Name of Second/Joint Inventor (given name, family name)

Ping-Sing Tsai

Inventor's Signature _____

Date _____

Residence _____
(City, State)

Citizenship _____
(Country)

P. O. Address _____

Full Name of Third/Joint Inventor (given name, family name)

Inventor's Signature _____

Date _____

Residence _____
(City, State)

Citizenship _____
(Country)

P. O. Address _____

Full Name of Fourth/Joint Inventor (given name, family name)

Inventor's Signature _____

Date _____

Residence _____
(City, State)

Citizenship _____
(Country)

P. O. Address _____

Full Name of Fifth/Joint Inventor (given name, family name)

Inventor's Signature _____

Date _____

Residence _____
(City, State)

Citizenship _____
(Country)

P. O. Address _____

002130-2921550

Full Name of Sixth/Joint Inventor (given name, family name) _____

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City, State) (Country)

P. O. Address _____

Full Name of Seventh/Joint Inventor (given name, family name) _____

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City, State) (Country)

P. O. Address _____

Full Name of Eighth/Joint Inventor (given name, family name) _____

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City, State) (Country)

P. O. Address _____

Full Name of Ninth/Joint Inventor (given name, family name) _____

Inventor's Signature _____ Date _____

Residence _____ Citizenship _____
(City, State) (Country)

P. O. Address _____

002190-42376550

Date _____

Citizenship _____
(Country)

P. O. Address _____

Date _____

Citizenship _____
(Country)

P. O. Address _____

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	

APPENDIX A

I hereby appoint BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, a firm including: William E. Alford, Reg. No. 37,764; Farzad E. Amini, Reg. No. 42,261; Amy M. Armstrong, Reg. No. 42,265; Aloysius T. C. AuYeung, Reg. No. 35,432; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Ronald C. Card, Reg. No. 44,587; Thomas M. Coester, Reg. No. 39,637; Donna Jo Coningsby, Reg. No. 41,684; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Matthew C. Fagan, Reg. No. 37,542; Tarek N. Fahmi, Reg. No. 41,402; George L. Fountain, Reg. No. 36,374; Paramita Ghosh, Reg. No. 42,806; James Y. Go, Reg. No. 40,621; James A. Henry, Reg. No. 41,064; Willmore F. Holbrow III, Reg. No. 41,845; Sheryl Sue Holloway, Reg. No. 37,850; George W. Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; William W. Kidd, Reg. No. 31,772; Sang Hui Kim, Reg. No. 40,450; Eric T. King, Reg. No. 44,188; Erica W. Kuo, Reg. No. 42,775; Michael J. Mallie, Reg. No. 36,591; Paul A. Mendonsa, Reg. No. 42,879; Darren J. Milliken, Reg. No. 42,004; Chun M. Ng, Reg. No. 36,878; Thien T. Nguyen, Reg. No. 43,835; Thinh V. Nguyen, Reg. No. 42,034; Dennis A. Nicholls, Reg. No. 42,036; Lisa A. Norris, Reg. No. 44,976; Daniel E. Ovanezian, Reg. No. 41,236; William F. Ryann, Reg. No. 44,313; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Jeffrey S. Smith, Reg. No. 39,377; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; Joseph A. Twarowski, Reg. No. 42,191; Lester J. Vincent, Reg. No. 31,460; Glenn E. Von Tersch, Reg. No. 41,364; John Patrick Ward, Reg. No. 40,216; Charles T. J. Weigell, Reg. No. 43,398; James M. Wu, Reg. No. 45,241; Steven D. Yates, Reg. No. 42,242; and Norman Zafman, Reg. No. 26,250; my attorneys; and Andrew C. Chen, Reg. No. 43,544; Justin M. Dillon, Reg. No. 42,486; and John F. Travis, Reg. No. 43,203; my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (714) 557-3800, and Alan K. Aldous, Reg. No. 31,905; Robert D. Anderson, Reg. No. 33,826; Joseph R. Bond, Reg. No. 36,458; Richard C. Calderwood, Reg. No. 35,468; Jeffrey S. Draeger, Reg. No. 41,000; Cynthia Thomas Faatz, Reg. No. 39,973; Sean Fitzgerald, Reg. No. 32,027; John N. Greaves, Reg. No. 40,362; Seth Z. Kalson, Reg. No. 40,670; David J. Kaplan, Reg. No. 41,105; Charles A. Mirho, Reg. No. 41,199; Leo V. Novakoski, Reg. No. 37,198; Naomi Obinata, Reg. No. 39,320; Thomas C. Reynolds, Reg. No. 32,488; Kenneth M. Seddon, Reg. No. 43,105; Mark Seeley, Reg. No. 32,299; Steven P. Skabrat, Reg. No. 36,279; Howard A. Skaist, Reg. No. 36,008; Steven C. Stewart, Reg. No. 33,555; Raymond J. Werner, Reg. No. 34,752; Robert G. Winkle, Reg. No. 37,474; and Charles K. Young, Reg. No. 39,435; my patent attorneys, and Thomas Raleigh Lane, Reg. No. 42,781; Calvin E. Wells, Reg. No. P43,256; Peter Lam, Reg. No. 44,855; and Gene I. Su, Reg. No. 45,140; my patent agents, of INTEL CORPORATION; and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.